COMMENTS

By the present amendment Applicant has merely deleted references to the omitted drawings and to reference numerals contained therein. The text has been maintained and no new matter has been added.

Also, a change in dependency has been made in claims 9 and 10.

A marked up copy of the amended paragraphs showing the changes made is attached separately hereto.

It is not believed that any fees are due in connection with this amendment, but any fees or credits which are due may be charged to Graftech Deposit Account No. 50-1202.

Respectfully submitted,

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MARKED UP VERSION OF AMENDED PARAGRAPHS

Page 5, line 8 - Page 6, line 5:

[Brief Description of the Drawings

FIG. 1 is a plan view of a transversely permeable sheet of flexible graphite having transverse channels in accordance with the present invention;

FIG. 1(A) shows a flat-ended protrusion element used in making the channels in the sheet of Figure 1;

FIG. 2 is a side elevation view in section of the sheet of Figure 1;

FIGS. 2(A), (B), (C) show various suitable flat-ended configurations for transverse channels in accordance with the present invention;

FIGS. 3, 3(A) shows a mechanism for making the article of Figure 1;

FIG. 4 is a scanning view electron microscope (SEM) at an original magnification of 50X showing natural graphite flake sized in the range of 80 x 140 mesh.

FIG. 5 is a sketch of an enlarged elevation view of an article formed of flexible graphite sheet having transverse channels for use with the present invention;

FIG. 6 is a top plan view of an article formed of the sheet material of Figure 1 having a continuous open top groove formed in its upper surface in accordance with the present invention;

FIG. 6(A) is a sectional side elevation view of the material of the article of Figure 6; and

FIGS. 7, 8 and 8(A) show a fluid permeable electrode assembly which includes a transversely permeable article in accordance with the present invention.]

<u>Brief Description of the Drawing</u>

<u>The figure is a scanning view electron microscope (SEM) at an original magnification of 50X showing natural graphite flake sized in the range of 80 x 140 mesh.</u>

<u>Page 12, line 10 - Page 15, line 15:</u>

[With reference to Figure 1, a] <u>A</u> compressed mass of expanded graphite particles <u>is provided</u>, in the form of a flexible graphite sheet [is shown at 10]. As noted above, the graphite flake used in to produce the expanded graphite particles is sized such that no more than about 30% by weight of the flake is +80 mesh (U.S. standard screen). Most preferably, graphite flake is sized at least about 50% by weight 80 x 140 mesh, U.S. standard screen and has a moisture content of no greater than about 1.0%. The flexible graphite sheet [10] is provided with channels [20], which are preferably smooth-sided [as indicated at 67 in Figure 5], and which pass between the opposed surfaces [30, 40] of <u>the</u> flexible graphite sheet [10], and are separated by walls [3] of compressed expandable graphite. The channels [20] preferably have openings [50] on one of the opposed surfaces [30] which are larger than the openings [60] in the other opposed surface [40]. The channels [20] can

have different configurations [as shown at 20' - 20''' in Figures 2(A),2(B),2(C)] which are formed using flat-ended protrusion elements of different shapes [as shown at 75, 175, 275, 375 in Figures 1(A) and 2(A),2(B),2(C)], suitably formed of metal, e.g. steel and integral with and extending from the pressing roller [70] of the impacting device [shown in Figure 3]. The smooth flat-ends of the protrusion elements [shown at 77, 177, 277, 377], and the smooth bearing surfaces [73, of roller 70, and the smooth bearing surface 78 or roller 72] of a pair of rollers (or alternatively one roller and a flat metal plate [79]), ensure deformation and complete displacement of graphite within the flexible graphite sheet, i.e. there are no rough or ragged edges or debris resulting from the channel-forming impact. Preferred protrusion elements have decreasing cross-section in the direction away from the pressing roller [70] to provide larger channel openings on the side of the sheet that is initially impacted. The development of smooth, unobstructed surfaces [63] surrounding channel openings [60], enables the free flow of fluid into and through smooth-sided [(at 67)] channels.

In a preferred embodiment, openings on one of the opposed surfaces are larger than the channel openings in the other opposed surface, *e.g.* from 1 to 200 times greater in area, and result from the use of protrusion elements having converging sides [such as shown at 76, 276, 376]. The channels [20] are formed in the flexible graphite sheet [10] at a plurality of pre-determined locations by mechanical impact at the predetermined locations in sheet [10] using a mechanism [such as shown in Figure 3] comprising a pair of steel rollers [70, 72] with one of the rollers having truncated, i.e. flat-ended, prism-shaped protrusions [75] which

impact <u>the</u> surface [30] of <u>the</u> flexible graphite sheet [10] to displace graphite and penetrate <u>the</u> sheet [10] to form open channels [20]. In practice, both rollers [70, 72] can be provided with "out-of-register" protrusions, and a flat metal plate [indicated at 79], can be used in place of <u>a</u> smooth-surfaced roller [72].

This orientation of the expanded graphite particles [80] results in anisotropic properties in flexible graphite sheets; i.e. the electrical conductivity and thermal conductivity of the sheet being substantially lower in the direction transverse to <u>the</u> opposed <u>major</u> surfaces [130, 140] ("c " direction) than in the direction ("a" direction) parallel to <u>the</u> opposed <u>major</u> surfaces [130, 140]. In the course of impacting <u>the</u> flexible graphite sheet [10] to form channels [20, as illustrated in Figure 3], graphite is displaced within flexible graphite sheet [10] by flat-ended [(at 77)] protrusions [75] to push aside graphite as it travels to and bears against <u>the</u> smooth surface [73] of <u>the</u> roller [70] to disrupt and deform the parallel orientation of <u>the</u> expanded graphite particles [80 as shown at 800 in Figure 5]. This region [of 800], adjacent <u>the</u> channels [20], [shows] <u>showing</u> disruption of the parallel orientation into an oblique, non-parallel orientation is optically observable at magnifications of 100X and higher. In effect the displaced graphite is being "die-molded" by the sides [76] of adjacent protrusions [75] and the smooth surface [73] of roller [70 as illustrated in Figure 5]. This reduces the anisotropy in <u>the</u> flexible graphite sheet [10] and thus increases the electrical and thermal conductivity of <u>the</u> sheet [10] in the direction transverse to the opposed <u>major</u> surfaces [30, 40]. A similar effect is achieved with frusto-conical and parallel-sided peg-shaped flat-ended protrusions [275 and 175].

In the practice of the present invention, [with reference to Figures 6 and 6(A),] a gas permeable flexible graphite sheet [10, as shown in Figure 1,] is provided, at one of its surfaces [30] with a continuous, open groove [300], a fluid inlet [303] and a fluid outlet [305] to constitute a gas diffusing electrode [610]. The groove [300] of the present invention is suitably formed by pressing a hard metal die onto the inventive flexible graphite sheet material, [such as material of the type shown in Figure 2,] *i.e.*, flexible graphite sheet having transverse channels [20] passing therethrough from surface [30] to surface [40]. The die forms a continuous open groove [300] in the surface contacted by the die. For a sheet of flexible graphite 0.15 mm to 0.32 mm thick, the open groove [300] can be, for instance, 0.076 mm to 0.16 mm deep and 0.5 mm to 0.6.35 mm wide separated by lands [400] that are 0.25 mm to 1.6 mm thick.

The perforated gas permeable flexible graphite sheet [10 of Figure 1] can be used as an electrode in an electrochemical fuel cell [500 shown schematically in Figures 7, 8 and 8(A)].

[Figure 7, Figure 8 and Figure 8(A) show, schematically, the] The basic elements of an electrochemical Fuel Cell[, more complete details of which] are disclosed in U.S. Patents 4,988,583 and 5,300,370 and PCT WO 95/16287 (15 June 1995) [and] each of which is incorporated herein by reference.

[With reference to Figure 7, Figure 8 and Figure 8(A), the] The Fuel Cell [indicated generally at 500,] comprises electrolyte in the form of a plastic e.g. a solid polymer ion exchange membrane [500]; perforated flexible graphite sheet electrodes [10] in accordance with the present invention; and flow field plates [1000, 1100]

which respectively abut <u>the</u> electrodes [10]. Pressurized fuel is circulated through grooves [1400] of fuel flow field plate [1100] and pressurized oxidant is circulated through <u>other</u> grooves [1200]. In operation, the fuel flow field plate [1100] becomes an anode, and the oxidant flow field plate [1000] becomes a cathode with the result that an electric potential, i.e. voltage is developed between the fuel flow field plate [1000] and the oxidant flow field plate [1100]. The above described electrochemical fuel cell is combined with others in a fuel cell stack to provide the desired level of electric power as described in the above-noted U.S. Patent 5,300,370.

The operation of <u>the</u> Fuel Cell [500] requires that the electrodes [10] be porous to the fuel and oxidant fluids, e.g. hydrogen and oxygen, to permit these components to readily pass from the grooves [1400, 1200] through electrodes [10] to contact the catalyst [600] on the surfaces of the membrane [500, as shown in Figure 8(A)], and enable protons derived from hydrogen to migrate through <u>the</u> ion exchange membrane [550]. In the electrode [10] of the present invention, channels [20] are positioned to adjacently cover grooves [1400, 1200] of the flow field plates so that the pressurized gas from the grooves passes through the smaller openings [60] of channels [20] and exits the larger openings [50] of channels [20]. The initial velocity of the gas at the smaller openings [60] is higher than the gas flow at the larger openings [50] with the result that the gas is slowed down when it contacts the catalyst [600] on the surface of membrane [550] and the residence time of gas-catalyst contact is increased and the area of gas exposure at the membrane [550] is maximized. This feature, together with the increased electrical conductivity of the flexible graphite electrode of the present invention enables more efficient fuel cell

operation. Alternatively, in certain circumstances it may be desirable to have the pressurized gas flow through the larger openings [50] of <u>the</u> channels [20] and exit through the smaller openings [60] of <u>the</u> channels [20].

<u>MARKED UP VERSION OF THE CLAIMS</u>

9. The flexible graphite sheet of claim [8] <u>7</u> which further comprises a plurality of transverse fluid channels formed in the compressed sheet at a plurality of predetermined locations.

10. The flexible graphite sheet of claim [8] <u>7</u> which further comprises at least one groove formed in at least one of the surfaces of the sheet by mechanically impacting an opposed surface of the sheet.